Chapter 4 Communications Trunk Conduit System

4.1 Purpose

The Freeway Management System (FMS) communications system consists of either one or two trunk conduit systems that run parallel to the mainline freeway. These trunk conduits provide the primary method of distributing fiber-optic communications cabling and power conductors for the system.

FMS conduits that are not part of the trunkline conduit system are typically called *branch* conduits. Branch conduits connect the trunkline network to the various field cabinets and devices. Branch lines shall connect to the TI signals and a second pullbox adjacent to the Traffic Signal for eventually maintenance by the local jurisdiction. Branch is often used to describe fiber tail circuits. Within this document, branch fiber-optic cables are described as tail-circuit fiber, contained within branch conduits.

4.2 Position of Trunkline within Freeway Right-of-Way

The trunkline conduit network shall be located inside and along the edge of the freeway's right-of-way line. Generally, the trunk conduit should be located as far from the mainline edge of pavement as feasible such that future widening of the mainline freeway will not impact it. The likelihood of future earthwork and re-grading decreases on approach to the right-of-way line. Thus, the trunkline conduit network is less likely to be disturbed by this work.

The designer will have to exercise engineering judgment as to the preferred location for the trunk line conduit system, considering such factors as slopes, cross-section, proximity to retaining walls, sound walls, landscaping and irrigation systems. Maintenance force access to the trunk conduit system, usually at pullboxes, should also be considered. The trunkline conduits should be offset from the actual right-of-way fence, where feasible, to avoid repeated maintenance vehicle wheel-loads. Several figures are included to illustrate these design concepts. (See Figures 4-1, 4-2, 4-3, 4.4, 4.6, and 4.9.)

When the freeway is on an embankment section, consideration must be given to the placement of field equipment, controller cabinets, etc. at the top of slope to provide visibility for the FMS equipment from the cabinet, even though the trunk line remains adjacent to the right-of-way line. In any case, trunk line should not be placed below slopes.

4.3 Trunkline Conduit Array & Layout

This section describes several trunkline conduit configurations intended to complete the existing FMS trunk conduit network and the future expansion of the FMS in a consistent manner. The industry has dynamically changed over the past few years with regard to conduit systems. Conduit size, trenching/backfill or directional drilling, etc. are among the most expensive, yet important elements of the

FMS. Many of these potential changes were considered exhaustively during the development of this guide.

4.3.1 Conduit Array: Three 3-Inch Conduits

The trunkline conduit array for the completion of existing urban freeways (Phoenix: Loop 101, Loop 202, SR-51, US-60, I-10 and I-17 and in Tucson: I-10 and I-19) shall be consistent with a three 3-inch conduit array. This three 3-in. conduit array has been used extensively in the existing network and is the ADOT standard.

Future build-out of new routes, such as Loop 202 South Mountain, Loop 303, I-10 R, and the Williams Gateway freeways in Phoenix may be configured with a different conduit array. Alternate conduit systems for future build-out could include quad-ducts and HDPE alternatives (see Section 4.5.2 for a discussion of conduit materials). Future options for innerducts (see Section 4.6) within the conduit system include micro-ducts and flexible, fabric innerducts.

Section 4.3.2 provides further discussion of trunkline conduit orientation, including vertical and horizontal configurations.

4.3.2 Conduit Layout

The ADOT FMS in Phoenix is approaching 100% build-out for all freeways interior to Loop 101 and Loop 202. It is ADOT's intention to complete the core FMS by continuing the construction of the three 3-inch conduit array. Redundant communication achieved through looped rings may eliminate the need for the conduit array on both sides of the freeway. Regional connectivity goals for local agencies may require the need for fiber-optic cable installation within the spare conduit, and this issue should be carefully discussed with the Transportation Technology Group (TTG) project manager (PM).

4.3.2.1 Trunkline on Both Sides of Freeway

Three 3-inch trunkline conduits are required along both sides of the freeway to accommodate communication cables and power cables, and to provide for future expansion of the FMS. Certain segments of the FMS trunkline may also include a fourth conduit for roadway lighting. The conduit path shall be chosen to provide a continuous conduit system as shown in Figure 4.1 and Figure 4.2.

4.3.2.2 Trunkline on One Side of Freeway

Where designated by the TTG PM, the conduit path for the trunkline conduit system may be constructed on only one side of the freeway. The conduit path for a "one-side" trunkline layout should incorporate the layout shown in Figure 4.3. This layout allows for future construction of the second trunkline on the opposite side of the respective freeway and frequent crossings to connect devices on both sides of the freeway. When the trunkline is constructed on one side of the freeway, it should generally be positioned on the same side of the freeway throughout the length of the freeway segment.

The parallel, deferred second trunkline conduit path should be examined during the initial design phase for costly future installation issues. For example, it may be prudent to place a concurrent, second, parallel conduit system over or under a canal, railroad, drainage way, connector ramp, major arterial, etc., along with the primary trunkline, if there is reasonable expectation that a future second trunkline will be constructed.

The single trunkline configuration will generally be limited to segments where communication redundancy (e.g., a second path to another node building) is immediately available by means other than the second trunkline within the same corridor. The ADOT TTG must approve all single trunk segments prior to design.

Figure 4.3 also depicts the recommended construction of a portion of the second trunkline at crossroad interchanges. Portions of a second trunkline must be connected via a crossing of the mainline to the adjacent trunkline. One connection between the two trunklines is required along either side of each major crossroad. A second optional lateral connection may be made near the on-ramp connection to the mainline.

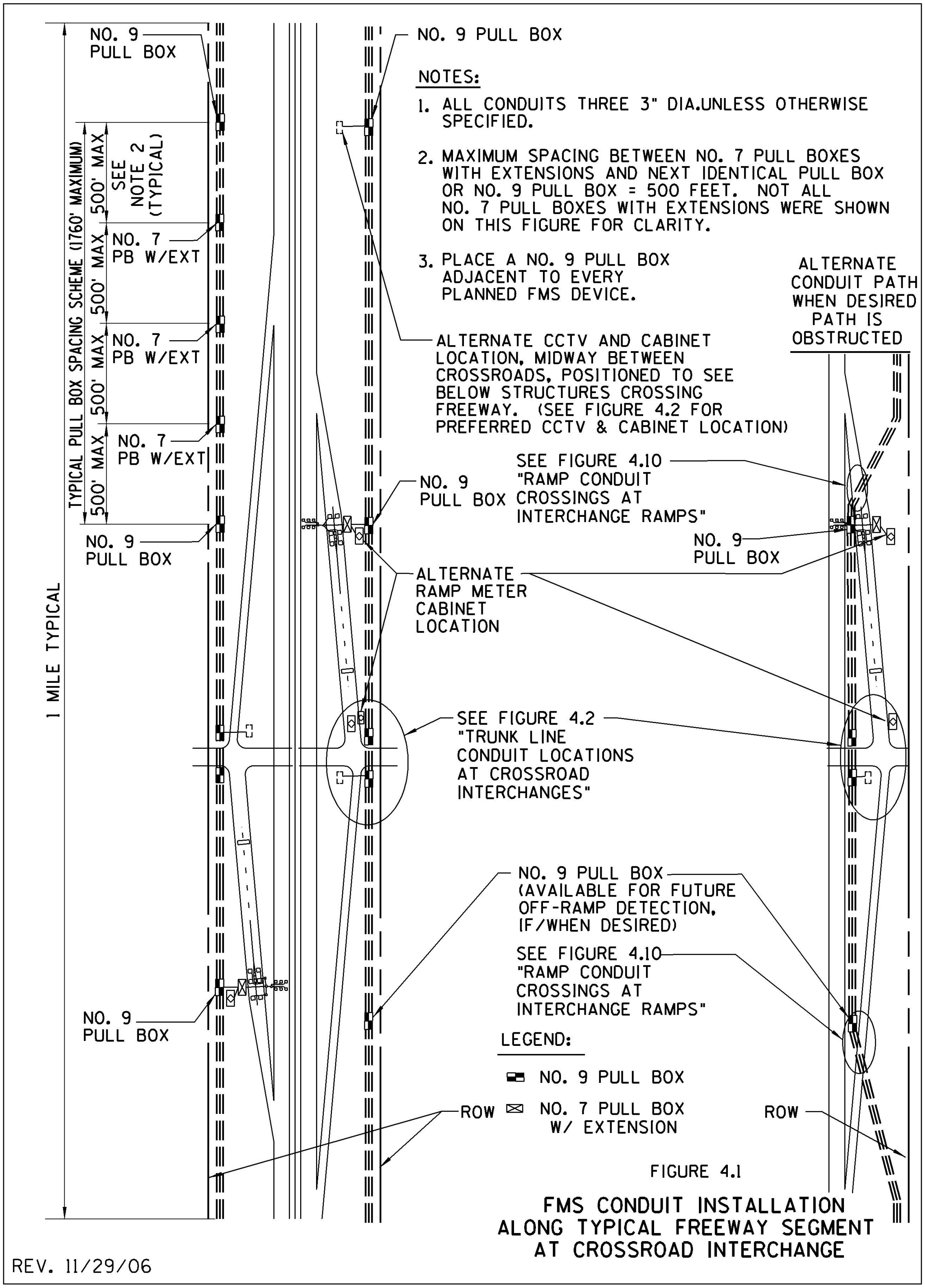

Figure 4.1 Crossroad Interchange Conduit Installation

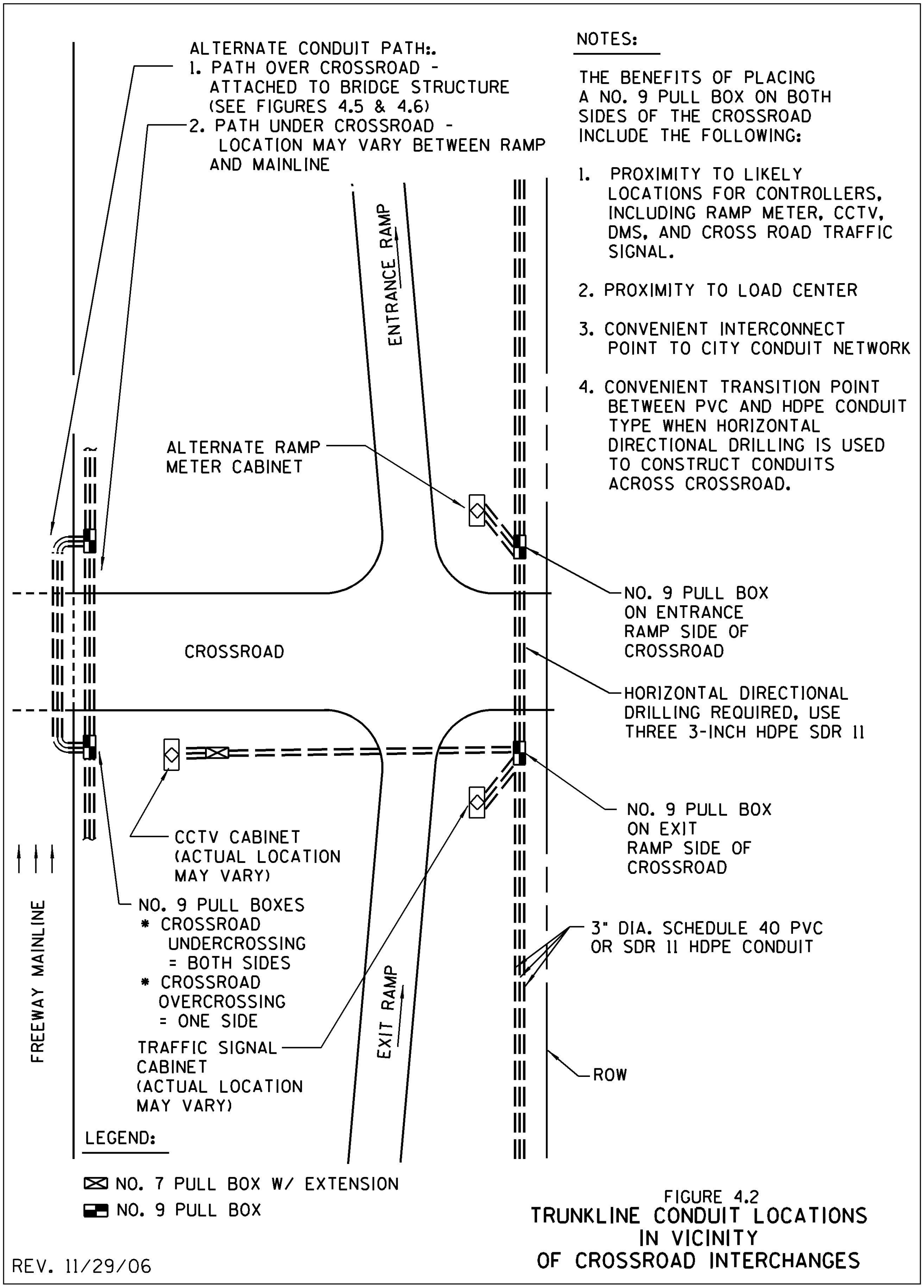

Figure 4.2 Crossroad Interchange Conduit Locations

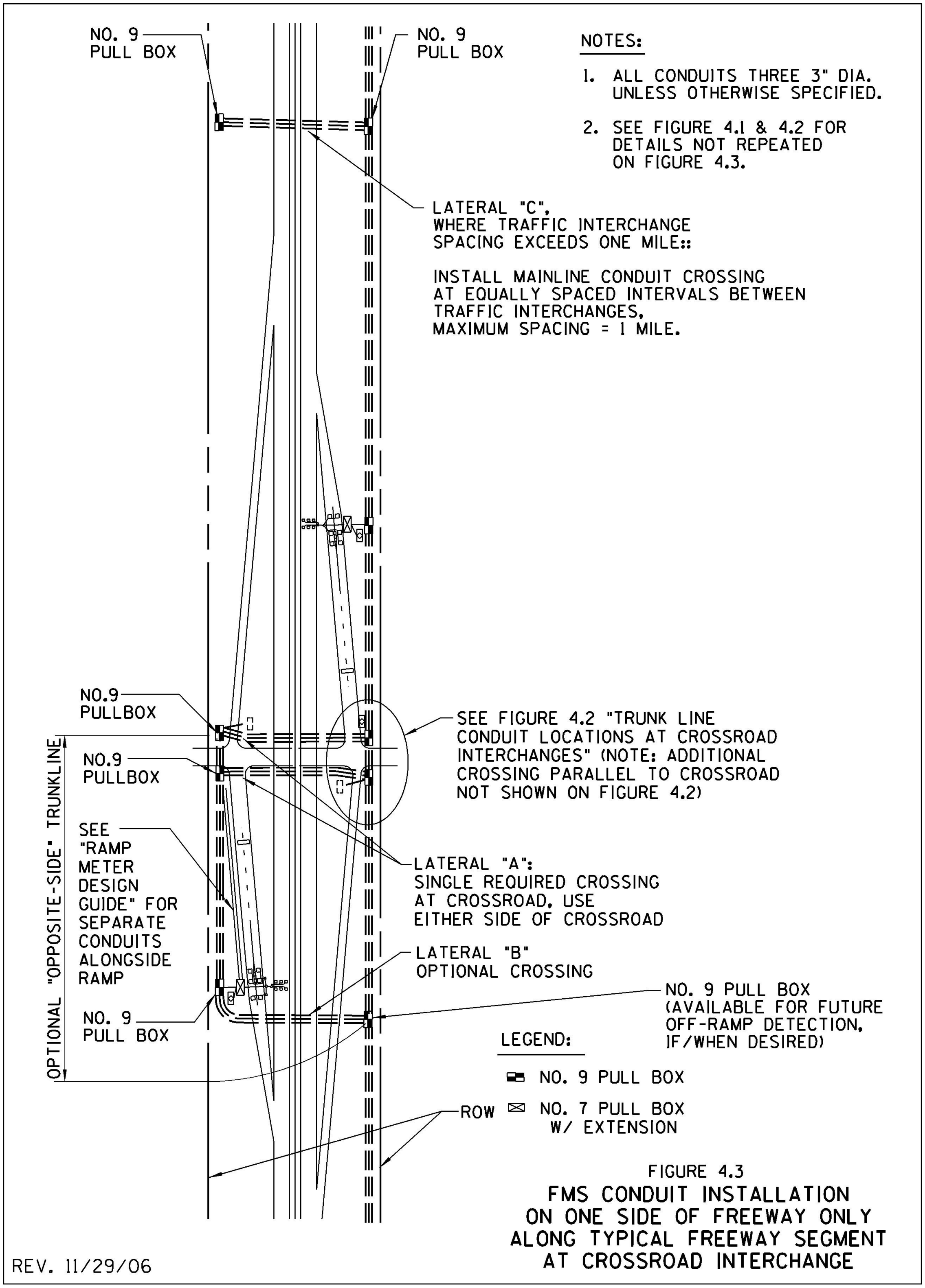

Figure 4.3 Conduit Installation on One Side of Freeway

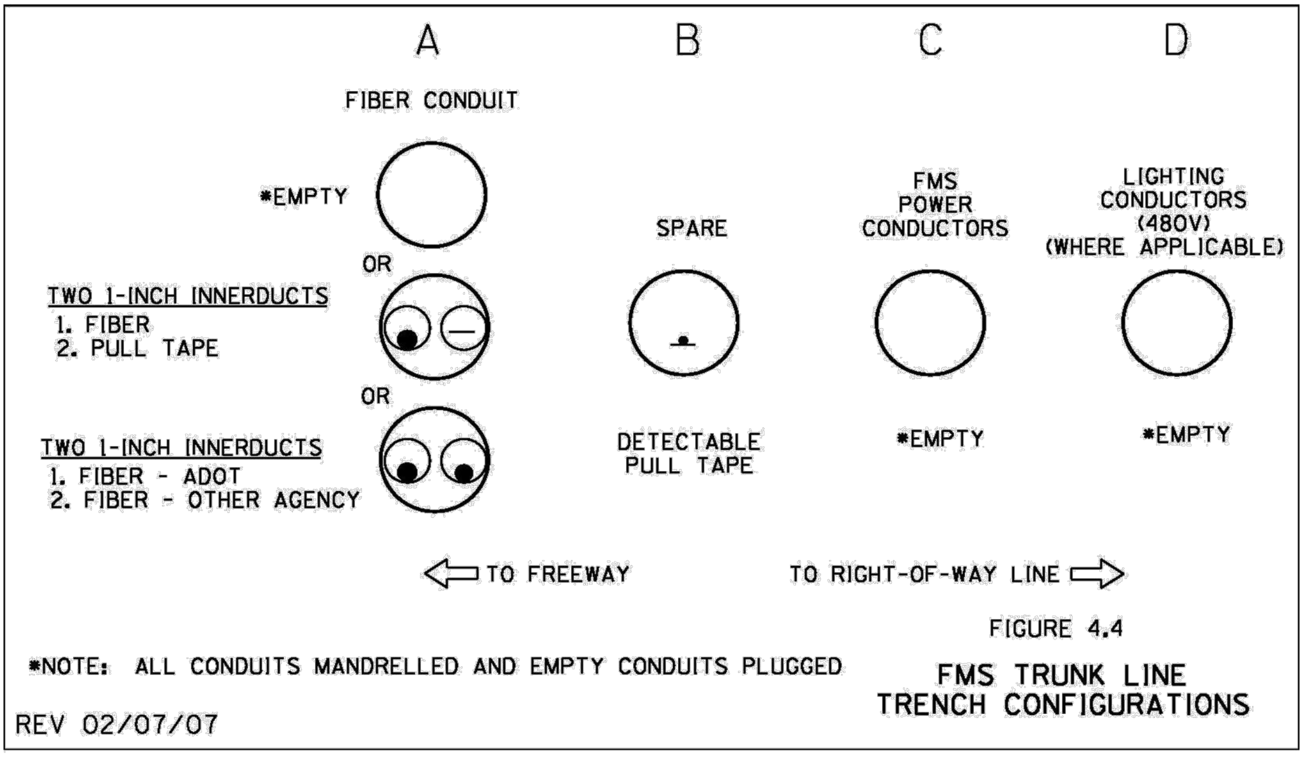

Figure 4.4 Trunk Line Trench Configurations

The principal three-inch trunkline conduit contents are described herein and in Figure 4.4:

1. The conduit closest to the freeway (horizontal array) or on top (vertical array) is designated for single mode fiber-optic (SMFO) cable, local agency fiber-optic cables, and other select device cables. All cables installed within the *fiber* conduit must be contained in innerduct (section 4.6). Loose fiber-optic cables outside of innerducts are not preferred.

2. The second conduit (center) will be reserved for future FMS purposes and shall contain the *detectable pull tape*. This detectable pull tape is to be installed in the conduit as part of the initial conduit installation. The detectable pull tape shall be minimum 2500 lb strength and #22 AWG conductor. If this conduit is eventually utilized by ADOT or a third party under a resource sharing agreement, they shall install a replacement *detectable pull tape* in the center conduit along with any cables, insuring detectability of the conduit system. This shall conform to legal requirements for detection.

3. The third conduit is designated for FMS device electrical power distribution. Other select power cables, where required, such as power to ramp meter poles may also be allowed within an innerduct array.

4. The fourth conduit is reserved for roadway lighting, when appropriate. (see Lighting Conduit – See Section 4.4). This is not a preferred design standard and is shown only to demonstrate legacy design.

4.4 Trunk Conduit Co-Location with Lighting Power Conduits

It is incumbent upon the designer to analyze the cost effectiveness of joint trenching versus separate systems. As a general rule, if the length of the laterals necessary to connect the roadway lighting accessories to the trunkline exceed half the distance separating the roadway lighting appurtenances, then separate systems may be more cost effective since the total conduit and trench path would be greater for a joint system. Typically, the trunk line follows the right-of-way line to avoid impact by future widening. Separating lighting from fiber may alleviate theft or destruction of fiber in conjunction with copper lighting conductor theft. A cost analysis of both options should consider both one-time construction costs and ongoing maintenance costs. Any construction cost savings should be weighed against potentially higher maintenance costs.

When lighting conduit is co-located with the FMS trunkline conduit system, No. 7 lighting pullboxes should be located near each of the FMS trunkline pullboxes. In all cases, lighting circuit conductors and the FMS power conductors shall not share the same pullbox. See Section 4.7.2.

4.5 Materials - Conduits

This section describes direct bury and HDD conduits. Section 4.6 describes innerducts within conduits.

4.5.1 Conduit Connections at Communications Nodes and FMS Segment End Points

This section describes the conduit connections at communication nodes and termination points.

Communication Nodes

At each communication node building, redundant (geographically separated) conduits shall be provided to interconnect the trunk conduits. Trunk conduits can either be extended along both sides of the freeway or be configured in a ring to accomplish this geographic separation. Three (3) three-inch-diameter conduits should provide interconnectivity between the node building and the two trunk lines being used for redundancy. These conduits may be installed in one of several locations including under the mainline freeway via directional drilling, along the crossroad at a bridge underpass, or attached transversely to overpass bridge structures (see Section 4.5.4).

Trunk line Segment Termination Points

The designer should coordinate the lateral and vertical placement of trunk conduits at project limits with adjacent design projects to ensure continuity of the conduit system and to ensure separation from other utilities.

4.5.2 Conduit Materials and Construction Methods

Conduits are constructed with either PVC or HDPE. All conduits shall have smooth inner and outer walls. (Innerducts are discussed in Section. 4.6.) PVC conduits are rated by wall thickness and crush resistance. Schedule 40 is used for all applications where PVC is used. HDPE (High Density Polyethylene) conduit is also rated for crush resistance and tear resistance. HDPE is subjected to significant pulling tension when used in HDD (Horizontal Directional Drilling) applications. SDR (Size Diameter Ratio) is a term that equates internal diameter and wall thickness to a universal rating. SDR 11 is judged from experience to be highly resistant to tear and crush forces for FMS HDD applications. To summarize, all conduits shall be smooth-walled and a minimum of Schedule 40 PVC or SDR 11 HDPE.

4.5.2.1 PVC and HDPE

All outside plant (OSP) conduits should comply with NEMA TC-2 requirements.

- PVC pipe shall conform to ASTM D1784 and D1785, and UL 651 standard specifications. Fittings shall conform to NEMA TC-3 requirements.
- HDPE pipe shall conform to the standards published by the Plastics Pipe Institute (www.plasticpipe.org).
  - Direct bury: In open trench installations, HDPE (SDR11) pipe may be used instead of PVC Schedule 40. On long segments, continuous reels of HDPE may be easier to install than short PVC segments that require more labor to fit segments together. Fusion splices are required. Gluing is not sufficient for joining segments of HDPE conduit.
  - Horizontal Directional Drilling (HDD): HDPE is required for all HDD locations. Splices are prohibited. All HDD conduits shall terminate in a (No. 9) pull box.
- No connectors or fittings are allowed between sections of PVC and HDPE pipe. All transitions between the two types of pipe shall occur at No. 9 pullboxes (See Section 4.7, Pullboxes).

4.5.2.2 Conduit Installation for Fiber-optic Cable: Maximum Pulling Tension, Bending Radius, and Deflection

The designer is responsible for designing a conduit system that will facilitate fiber-optic cable installation within, and assure that the exerted force on the cable will not exceed 600 pounds of pulling tension during installation. Fiber-optic cable tends to have less tensile strength than other types of cable. Cable pulling programs that calculate pulling tension, or previous design or construction experience are necessary to meet this requirement. Any bending is to be a gradual deflection of straight conduit, and (as described in the next subsection) no single bend is to exceed one inch of deflection in one foot.

4.5.2.3 Fiber-optic Conduit Deflection

Conduit deflection should not deviate more than 1 in. horizontally and/or vertically per foot of running length of conduit (1:12 Rule). Long conduit sweeps should be used wherever possible to change conduit direction. The design should strive to stringently adhere to this requirement in order to reduce the pulling tension required during cable installation.

It is recognized that there are complex conduit sites that have to be addressed during design, such as crossings over canals, tunnels, transitions into structures, etc where a 1:12 rule cannot be achieved. Where long conduit sweeps are not possible, standard factory made conduit elbows of 11 ¼, 22 ½ or 45 degrees with a minimum radius of 24 inches should be specified. 90 degree cumulative turns must be made up of individual elbows. Where complex sites leave no other option, such as into and out of structures, and thus requiring near 90 degree turns, a minimum radius of 36 inches is required. Ninety-degree elbows should be avoided, as they require additional labor and equipment for cable installation, even on short runs. The smallest degree bend possible should be utilized to minimize cable installation challenges. There shall be no more than 360 degrees of cumulative bends between adjacent No. 9 pull boxes.

4.5.2.4 Conduit Traceability and Detection – "Blue Stake"

The design of the fiber-optic conduit and cable must strive to avoid both potential damage to the conduit system and damage to the cable. Loss of communications is a critical issue with regard to the FMS.

Detectable pull tape is a woven cloth tape that has a wire embedded. The tape is used to pull large cables through a conduit, as well as providing a means of locating the buried conduit with the aid of an electronic locator tool. Detectable pull tape reduces the labor costs to the Contractor during the FMS field inventory phase, to subsequent contractors as new cable is installed, to inspectors checking system integrity and to ADOT during maintenance and utility identification of the system. Therefore, a detectable pull tape shall be installed *in the center spare conduit of every trunkline array*. The tape shall be 2500-pound minimum strength, with an integral 22 gauge (AWG) detectable wire. Detectable pull tape should typically be paid for as a separate pay item since many of the new FMS projects use existing and new trunkline conduit arrays. The grounding of the detectable pull tape in a pullbox is not required.

Branch conduits shall be constructed as *electrical* conduits for detection purposes, using No. 8 bare bond wire for traceability in accord with the ADOT Standard Specifications (Section 732-3.01).

4.5.2.5 Conduit Protection

The following requirements are for any project that includes the installation of new FMS trunk conduit or installation of fiber-optic/power/communications cables within an existing conduit system:

- The Contractor shall mandrel each and every conduit using a metal-disc mandrel with a diameter of 90% (80% for HDPE) of the inside diameter of the conduit.
- Immediately after the FMS conduits are installed, they shall be plugged to prevent the intrusion of water, mud, gravel, etc. The conduits shall also be re-plugged immediately after they have been mandrelled. An approved conduit plug is required to seal the conduits. Innerduct ends shall also be appropriately sealed. The conduit plugging requirement is in lieu of the installation of detectable pull tape (with the exception of the spare conduit where the detectable pull tape is mandatory).
- All conduits should always be fully protected from prolonged HV sunlight exposure, which can damage the conduit.

4.5.3 Conduit Trenching and Backfill

Several configurations of the trunkline are available to the contractor during construction. The intent of allowing any of the approved configurations is to take advantage of the economy of initiative.

Limited right-of-way width may also dictate a certain configuration such as a vertical stack. Where the conduit configuration is not horizontal, the fiber conduit is usually on top.

Conduit manufacturers offer *conduit spacers* (also called *duct spacer)* as an accessory product to support the installation of multiple conduits in one trench. Spacers provide stability, consistent separation, and relieve direct stress for conduit materials in direct bury and concrete encased applications. When installed with proper spacing to avoid excessive point deflections, spacers permit the contractor to backfill with native material instead of more costly encasement materials.

When *conduit spacers* are not used, use of *Controlled Low Strength Material (CLSM)* is required. *CLSM* is a low strength version of *Utility Concrete for Miscellaneous Construction*, as described in the ADOT *Standard Specifications for Road and Bridge Construction*, Subsection 922. *CLSM* requires only 200 pounds (i.e. "two sacks") of cement per cubic yard, where *Utility Concrete* requires 470 pounds. *CLSM* is generally required in areas below existing improvements, since compacted native backfill could exhibit unacceptable settlement over time, leading to potential cracking or other structural failure of the improvement.

Generally, conduits may be arrayed vertically or horizontally. Two options for conduit alignment devices and their corresponding backfill guidelines are depicted in Table 4.1.

Table 4.1 Trench Conduit Alignment Device and Backfill Options

FIGURE	CONDUIT ALIGNMENT DEVICE	BACKFILL TYPE
(not illustrated)	Conduit Spacer	Compacted backfill (native material, AB slurry, sand), or CLSM, except *CLSM* is required below existing improvements, such as pavement, driveways, and sidewalks.
Figure 4.5	Option: Conduit Spacer or Rebar Tie-Downs	*CLSM* required

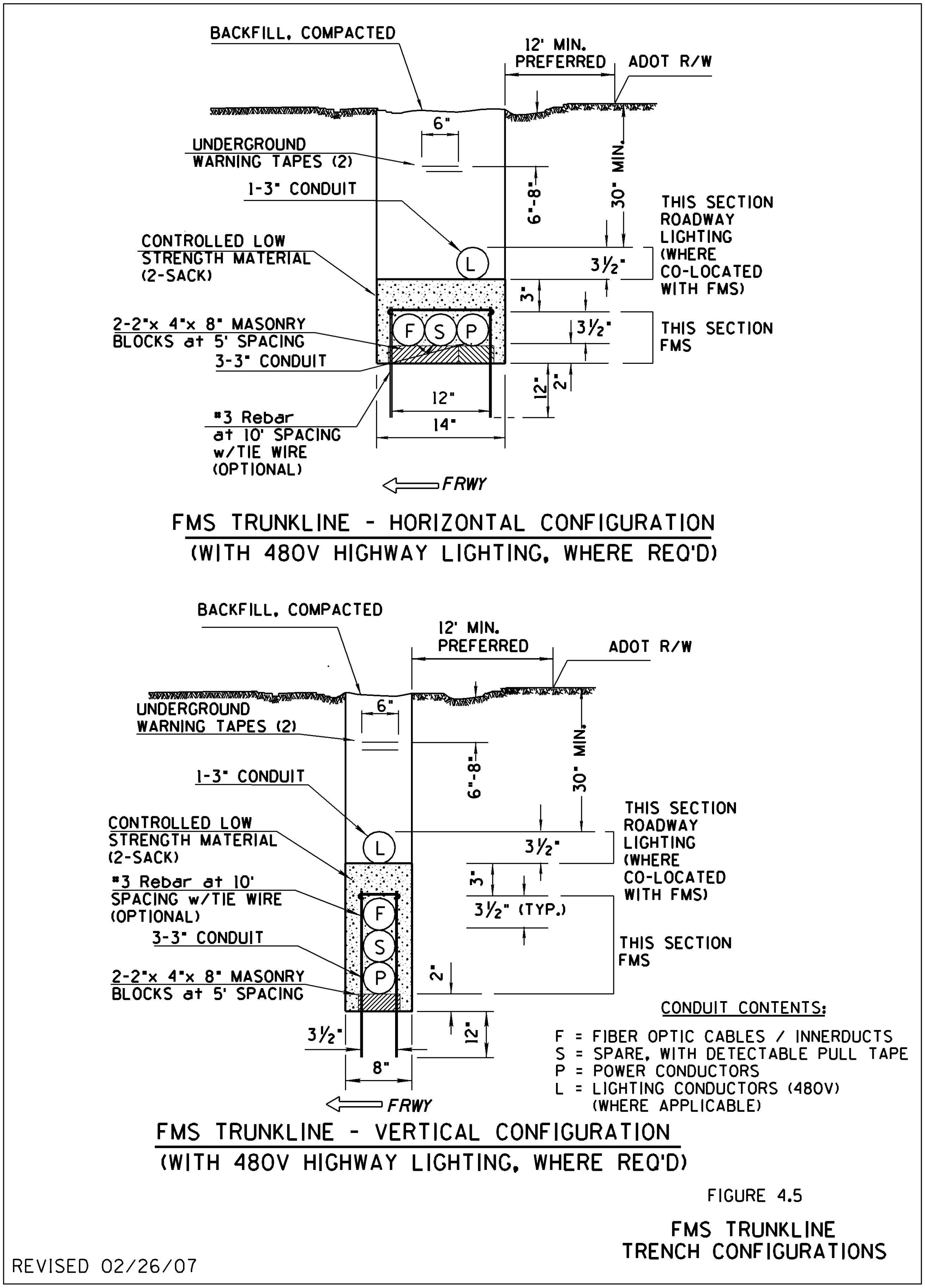

Figure 4.5 FMS Trunkline Trench Configuration CLSM Option

4.5.3.1 Trench Encasement Material

Trench encasement material is the backfill material that encapsulates the conduits when CLSM is not required. The requirements for trench encasement material are described in the *ADOT Standard Specifications for Road and Bridge Construction*, subsection 203-5.03(B)(1 – Structure Backfill), except that the gradation shall follow subsection 203-5.03(B)(2 – Use of Slurry) without the requirement of slurry material. Refer to the *FMS Standard Specifications* for additional information which may amend or supersede this specification.

4.5.3.2 Trench Backfill Material

Trench backfill material is the backfill material above the trench encasement material. Trench backfill material may be cementious or non-cementious in typical open trench situations.

- *CLSM* is not required, but remains an option for the Contractor. It is certainly possible that trench and conduit installation operations may be cost effectively installed with *CLSM*. Cementious slurry is *required* where conduits in open trench pass beneath existing pavement, including driveways, sidewalks, and other locations.
- Either AB slurry, sand, or native backfill meeting standard specifications for compacted backfill may be used for conduit backfill (See *ADOT Standard Specifications for Road and Bridge Construction*, subsection 501-3.04(A)(2 – Trench Backfill)).

4.5.3.3 Trench Configurations with Conduit Spacers

Where the conduit spacer option is used, conduit spacers shall be capable of separating the conduits vertically and horizontally by the following minimum amounts:

- TRENCH LONGITUDIAL:
  - Maximum longitudinal spacer separation = 10 feet
- VERTICAL:
  - Edge of trench to edge of spacer = 2 inches minimum
  - Bottom of trench to bottom of lowest conduit = 3 inches
  - Top of encasement material to top of highest conduit = 6 inches
  - Minimum stet conduit separation shall be the diameter of the largest encasement material (sieve size: 100% passing), and not less than 1½ inch.
- HORIZONTALLY:
  - Minimum horizontal conduit separation shall be twice the diameter of the largest encasement material (sieve size: 100% passing), and not less than 1½ inch.

Spacers should result in the conduit system behaving as a cohesive unit to prevent *floating* of the conduits during backfill. Spacers above the top conduits should be used to ensure that floating is observed and corrected during backfill operation, and to verify there is a minimum 30-inch cover above the top of the conduits (e.g., 24 in. above top of spacer).

4.5.4 Conduit Below Pavement and on Structure

This section describes conduits below pavement and on structures.

4.5.4.1 Conduit Installation on Structures: Bridges and Viaducts:

The ADOT Bridge Group must approve any conduit installation within or attached to a bridge structure. Attaching conduit and associated hardware to the exposed fascia of new structures should be avoided; the conduit should be incorporated into the structure where possible. Conduits either within or attached to structures will be rigid metal conduit (RMC). Rigid metal conduits are less likely to be affected by bridge expansion or deflection. Since this conduit is often hidden, it is imperative that the conduit system does not fail. Where required for aesthetic reasons, rigid metal conduits shall be painted to match the color of the existing bridge structure. Painting may require pre-treatment of the conduit.

Note: *This requirement may also be noted in the General Notes of the project plans.*

For bridge structures intended to convey the FMS trunkline or ramp conduits, a RMC conduit system will be installed inside the box girder cells or under the bridge deck between the exterior and first interior girders. Designers must ensure adequate expansion couplings, allowing for conduit movement in all planes. Expansion couple devices should be provided at the same locations of bridge movement points. See Figure 4.6.

The placement of the FMS conduits in structures less than 1,760 feet in length should be in conformance with Figure 4.6. No. 9 pullboxes should be placed on either end of every structure where the FMS conduit trunkline is to be installed. Figure 4.7 depicts the conduit transition treatment between structures and No. 9 pullboxes. Conduit hanger placement details for I-beam and concrete box girder bridges are shown in Figure 4.9. The elevation of the conduit through the structure should approximate the elevation of the conduit placement in the trench in order to avoid sharp directional changes. The use of 90º conduit elbows to transition the conduit from the trench to bridge grade is not acceptable.

For bridges over 1,760 feet in length, in additional to the No. 9 pullboxes on each end, an intermediate pullbox must be detailed into the structure to be accessible and to facilitate cable-pulling equipment. Intermediate pullboxes should be equally spaced along the structure at a maximum spacing of 1,760 feet. The designer will have to evaluate the accessibility of the area under or within the bridge to determine the appropriate location(s) for the intermediate pullbox(s). Select bridges may require field devices, such as CCTV and controller cabinets, to be structure mounted. These devices, along with the pullboxes and associated conduit system, require special design of barriers, platforms and pullboxes to accommodate the required field equipment.

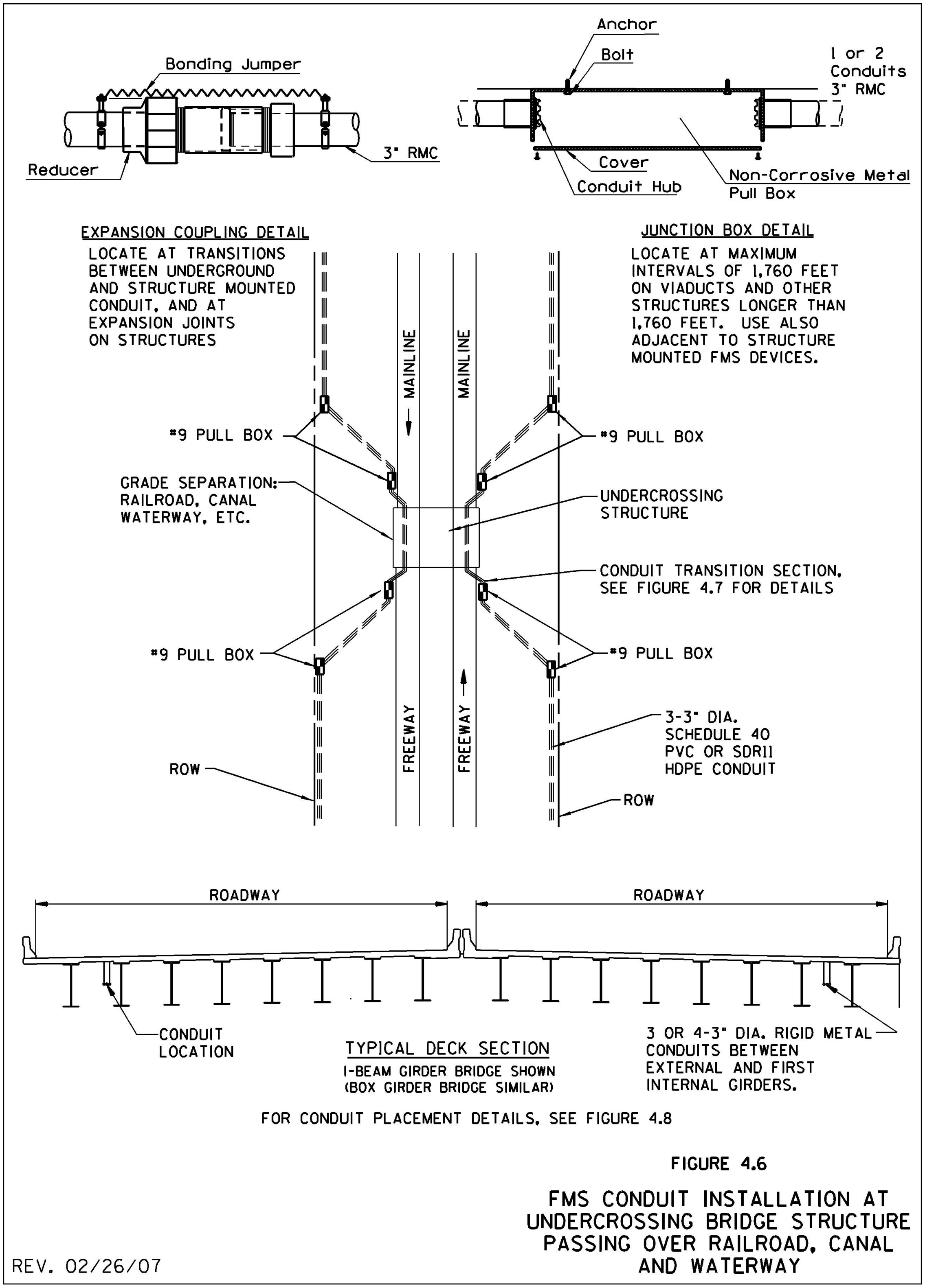

Figure 4.6 FMS Conduit Installation at Undercrossing Bridge Structure

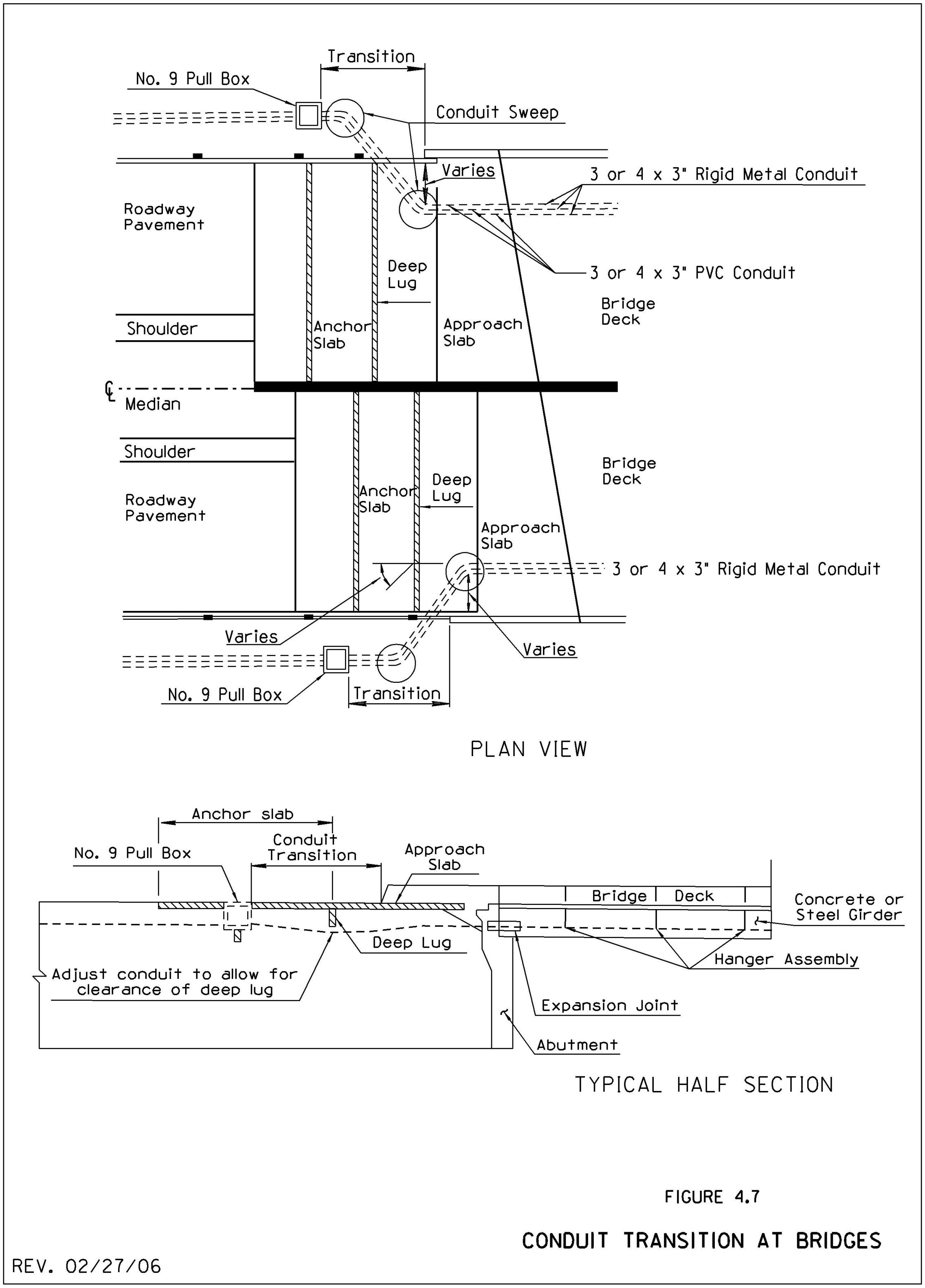

Figure 4.7 Conduit Transition at Bridges

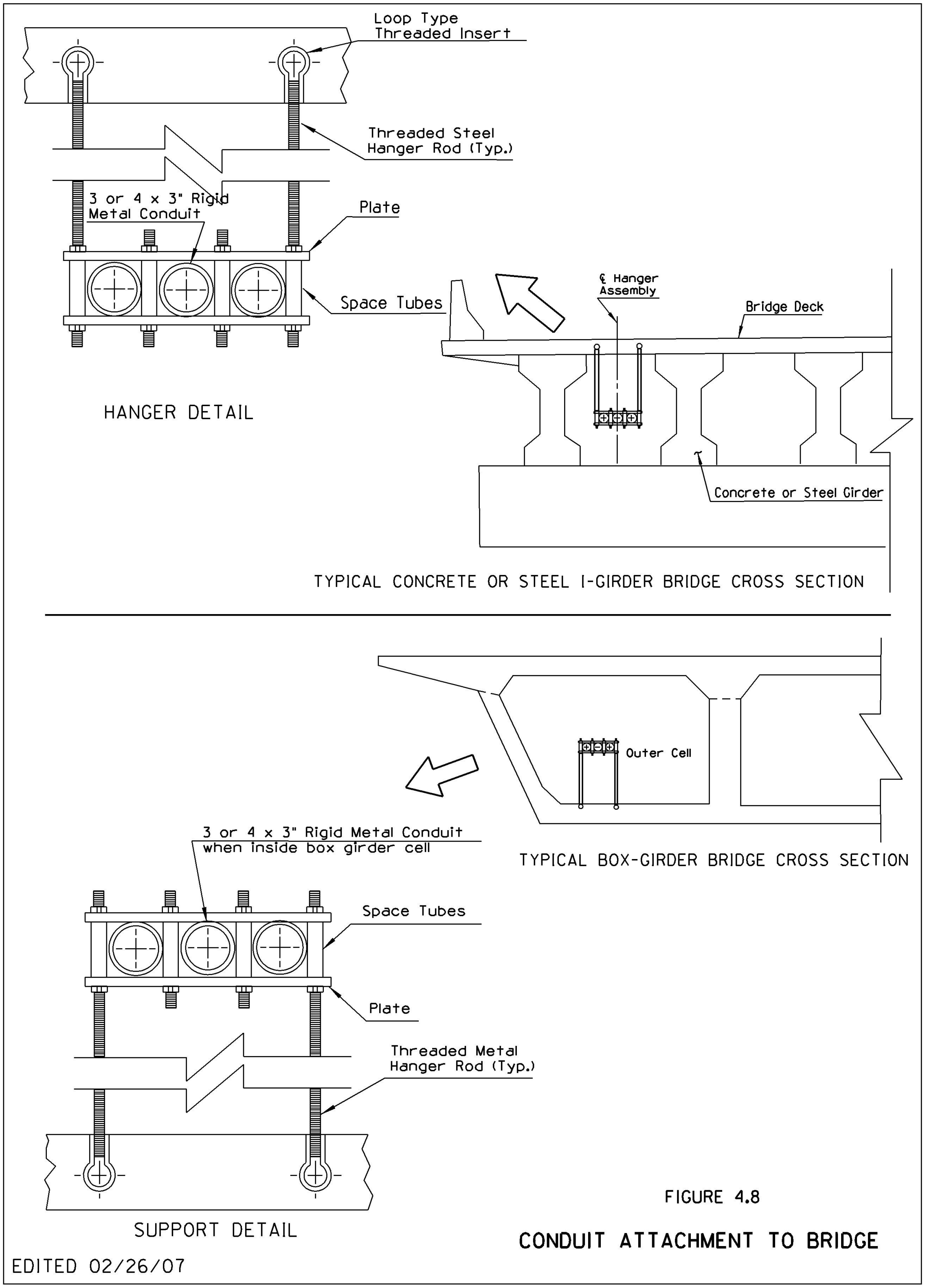

Figure 4.8 Conduit Attachment to Bridge

4.5.4.2 Conduits Crossing Ramps at Traffic Interchanges and System Interchanges

It is preferable to install trunk conduit along the right-of-way line, hence at traffic interchanges, the trunk conduits should be installed along the outside of the exit ramp, underneath the crossroad, and along the outside of the entrance ramp. In cases where this routing is not realistic, trunk conduit may cross the exit ramp, run alongside the mainline or inside of the entrance and exit ramps (crossing the crossroad either below pavement or on structure, see Figure 4.6, 4.7 and 4.8), and finally cross the entrance ramp back to outside of the entrance ramp (see Figure 4.9 for ramp conduit crossings). This alternate configuration is shown on the right side of Figure 4.1.

Three ramp conduit-crossing cases are shown on Figure 4.9 and Table 4.2. The *preferred* conduit path should be gradual (1:12 rule) to avoid use of factory conduit bends. Both the *acceptable* and *least desirable* paths shown in Figure 4.9 involve use of factory conduit bends, the latter using two 90 degree turns to cross the ramp.

Table 4.2 Ramp Conduit Crossing Cases

RAMP CONDUIT CROSSING OPTIONS (SEE FIGURE 4.10)		
CASE A	Preferred	No factory conduit bends, maximum deflection of one-inch per foot of conduit.
CASE B	Acceptable	Maximum factory bend of 22½º, 11¼º bend preferred.
CASE C	Least Desirable	90º factory bends, 36” radius.

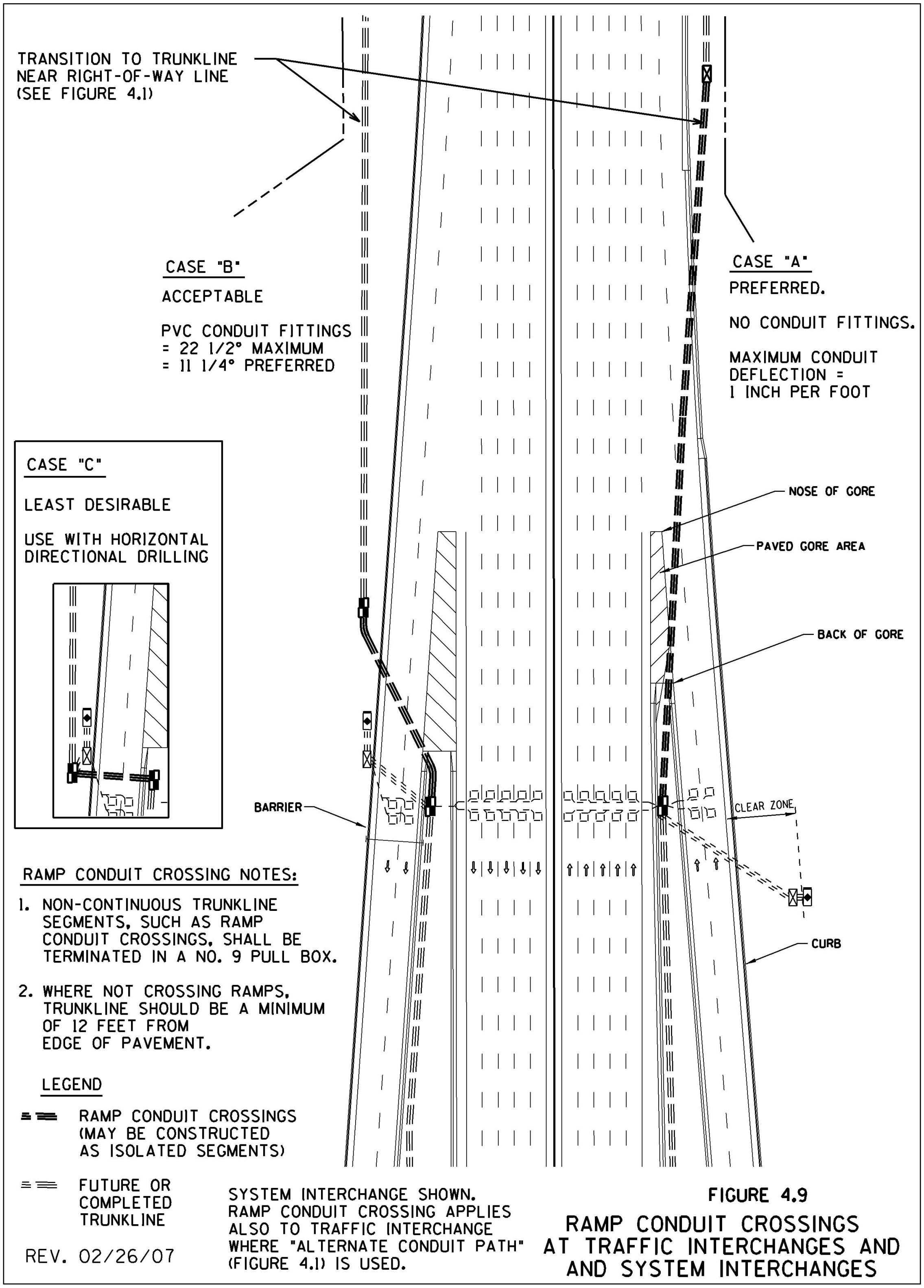

Figure 4.9 Ramp Conduit Crossings

4.5.4.3 Conduit for Future Roadway Crossings

For projects where the continuous trunkline conduit is not being installed as part of the roadway construction project, designs must include provisions for installing roadway crossings where needed for future use. Usually this will occur at transverse crossroads. The designer should coordinate closely with the ADOT TTG PM for design of the trunkline 3" FMS conduits needed for the crossing. Available construction options include:

- HDD methods
- Open trenching where the construction of the crossroad is part of the civil improvement, or where other unusual conditions exist, subject to ADOT TTG approval

Irrespective of construction methodology, all conduits terminate in a No. 9 pullbox. Transitions between two types of conduit (HDPE vs. PVC) must be made in a No. 9 pullbox.

4.5.5 Horizontal Directional Drilling (HDD)

The Contractor may utilize horizontal directional drilling (HDD) (also termed directional boring – DB) instead of conventional trenching at no additional compensation. The Contractor shall utilize HDD methods in locations under existing pavements, railroads, obstructions in areas where trenching would impact existing surface features, such as landscaping, that are not easily restored, and where indicated in the design plans. The designer should indicate HDD beginning and ending points on the plans. Warning tape is not required in conduit segments where HDD methods are used for construction.

The designer is referred to the following HDD reference documents:

- ASTM F 1962 – Standard Guide for Use of Maxi-Horizontal Directional Drilling for Placement of Polyethylene Pipe or Conduit Under Obstacles, including River Crossings.
- Mini Horizontal Directional Drilling Manual – published by the North American Society of Trenchless Technology (NASTT).
- Polyethylene Pipe for Horizontal Directional Drilling-published by the Plastic Pipe Institute (PPI).

4.6 Materials - Innerducts

As noted in Section 4.4, two innerducts are to be installed in the fiber-optic 3-inch trunk conduit when ADOT and other agency fiber-optic cables may be installed on the same project, or where one fiber is installed with the other fiber to be installed subsequently. Otherwise, no innerduct is to be installed in the trunkline conduits. Generally, two 1-in. innerducts of different color are to be installed in the 3-in. fiber-optic trunk conduit when required. One innerduct shall contain the ADOT fiber-optic cable. The other innerduct shall contain the other agency fiber-optic cable, or detectable pull tape (See Figure 4.4) to facilitate future fiber installation. While this detectable pulltape is redundant with the detectable pulltape within the center trunkline conduit, it is advisable to not require a different type of tape for this purpose.

Innerduct Types

All innerducts shall be HDPE products with a nominal 1 inch diameter. No PVC innerduct is permitted. The two basic types of innerduct are *smooth walled* and *corrugated*. Corrugated innerduct was developed specifically to carry fiber-optic cables within larger conduits.

Corrugated innerduct:

- Is not rated by SDR, but is rated by inner and outer diameter, maximum pull load, and other characteristics.
- Has advantages over smooth walled innerduct, including:
  - Greater flexibility and elasticity
  - Resistance to *ovalization*. Corrugated innerduct specifications generally call for a maximum ovalization of 5%, where smooth walled and ribbed innerducts allow 10%.
  - Resistance to *necking*. Smooth-walled innerduct tends to neck down at random points, where corrugated innerducts maintain their cross-section.
  - No *reel memory*. Smooth walled innerduct is more rigid resulting in a greater possibility of retaining some of the curvature it had when on the reel.
- Increased inside diameter. When pulled to near its tensile strength, the inside diameter of corrugated innerduct tends to increase.
- Lighter weight. The reduced weight of corrugated innerduct often more than offsets its reduced tensile strength.
- Is available in tensile strengths comparable to smooth walled SDR-13.5 innerduct.
- Is less suitable for runs over 1,000 feet.

Smooth walled innerduct is:

- Available in varying wall thickness, described by the SDR. SDR 13.5 is appropriate for FMS innerduct applications. The safe pulling tension for SDR 13.5 typically exceeds 400 lbs.
- Is more suitable for runs longer than 1,000 feet.
- *Ribbed* innerduct has longitudinal ribs on the inside, outside, or both surfaces. Outer ribs interlock with the ribs of the second innerduct, reducing *spiraling* of the two innerducts. Outer ribs also reduce the friction between the conduit and the innerduct during innerduct installation. Inner ribs reduce the friction between the innerduct and the fiber-optic cables during fiber installation. Both inner and outer ribs facilitate the spread of lubricants.
- The designer should consider various factors when choosing innerduct. Generally, *ribbed* innerduct is preferred for runs over 1,000 feet, and corrugated innerduct is preferred for shorter runs. However, where the tensile strength of corrugated innerduct is rated equal to or higher than that of SDR 13.5 smooth walled or ribbed innerduct, and there is no other apparent disadvantage to the corrugated product, corrugated innerduct may be considered for longer runs.

Innerduct Construction and Inspection

The specification for innerduct installation should include a requirement for the Contractor to blow a plug (pig) through the innerduct to demonstrate that the innerduct was installed properly (e.g., not twisted, crimped, necked or ripped) in accordance with industry practice.

4.7 Pullboxes

FMS pullboxes are used in ground and structure mounted applications. Two sizes or types of FMS ground-based pullboxes are normally used on FMS projects: The "box" sized *Number 7* and the "vault" sized *Number 9* (see Section 4.7.1 for further description of pullbox types). Pullboxes on slopes should normally be constructed with the lid level, not tilted to be parallel with the slope. Pullboxes should also be designed to avoid exposing the side of the pullbox that might be a hazard to traffic.

Pullboxes should not be installed within the roadway, any paved area, or future roadway footprint unless each location is explicitly approved by ADOT TTG and compliant with additional load and lid requirements where applicable.

Pullboxes should not be positioned in locations that are known paths for vehicles, such as maintenance and landscaping trucks, nor in roadway shoulder or distressed vehicle pullouts. Designers should field check each new proposed pullbox location to ensure that it is not in a location where it would likely be in the path of vehicle traffic.

Care should be taken in locating pullboxes to avoid drainage swales. Generally, pullboxes should be elevated above the surrounding terrain between one and two inches. Thus the requirement to have the designer pre-position the pullbox within the design is no longer required.

The field inspection team, along with the Contractor, must position pullboxes to avoid drainage swales or wheel-loads. Where necessary to avoid these locations, the pullbox spacing may be reduced and the number of pullboxes required increased. Pullbox locations can be more easily checked to avoid adverse locations if the contractor marks the proposed trunk line path in the field prior to construction.

Pullboxes should comply with NEC internal dimension requirements described in Article 314, with consideration of cable size and bending radius.

Delineators are not required to mark pullbox locations.

All pullbox lids shall be labeled "ADOT FMS," consistent with current practice.

4.7.1 Pullbox Types

Two types of FMS in-ground pullboxes, No. 9 and No. 7 with extension are illustrated in Figure 4.10, 4.11, and 4.12. See the *FMS Standard Details* for additional detailing of pullboxes. Pole mounted and bridge mounted pullboxes are also described in this section.

4.7.1.1 No. 7 Pullboxes with Extensions- General

All No. 7 pullboxes on FMS projects shall include extensions. As illustrated in, there are two types of No. 7 Pullboxes with extensions; one for use with fiber-optic tail circuits (on branch conduits only, all trunkline fiber shall pass only through No. 9 Pullboxes), and one for use with electrical conductors (for use on both trunkline and branch conduits). No. 7 pullboxes with extensions are installed along the trunk conduit system to facilitate cable pulling, to provide access to the trunk conduit system for power conductors, or for other laterals not requiring splicing or coiling of the fiber-optic cable. Electrical No. 7 pullboxes with extensions are to be located a maximum of 500 feet apart along the trunk conduit system. Typically, only the third conduit containing electrical conductors is swept up into the No. 7 pullboxes, while the remaining conduits bypass the box. Conduit entering No. 7 Pullboxes with extensions shall have molded bell ends to protect the conductors/conduit during installation. No. 7 pullboxes do not need to be numbered or geo-referenced.

4.7.1.2 No. 7 Pullboxes with Extensions- Loading Requirements

All FMS No. 7 pull boxes and extensions shall be designed, tested, and certified to meet AASHTO *"HS20-44"* and ASTM C 857 *"A-16"* loading requirements, including impact factor. The maximum AASHTO loading applies regardless of whether the older Load Factor Design (*LFD*) or newer Load and Resistance Factor Design (*LRFD*) methods are used, and is applicable to all pullbox elements except for steel lids. Typically, pullboxes that meet the loading requirements have steel lids and can be welded in place to prevent theft. While steel lids themselves have a lesser design load (using the steel allowable stress method); all items below the lid, including connecting hardware, lid seat, ring, or rim, and pullbox walls, shall be designed using the additional load factors. The *No. 7 Concrete Pull Box* shown on ADOT *Std Dwg T.S. 1-3* and the *No. 7 Concrete Pull Box Extension* shown on ADOT *Std Dwg T.S. 1-4* do not meet these loading requirements.

Sample design load calculations (except for steel lids), applied to any 8" x 20" area on the pull box lid:

LFD: 16,000 lbs x 1.3 x 1.67 x 1.3 = 45,157 lbs

LRFD: 16,000 lbs x 1.75x 1.2 x 1.33 = 44,688 lbs

Sample design load calculations for steel lids, applied to any 8" x 20" area on the pull box lid:

Allowable Stress Design: 16,000 lbs x 1.3 = 20,800 lbs.

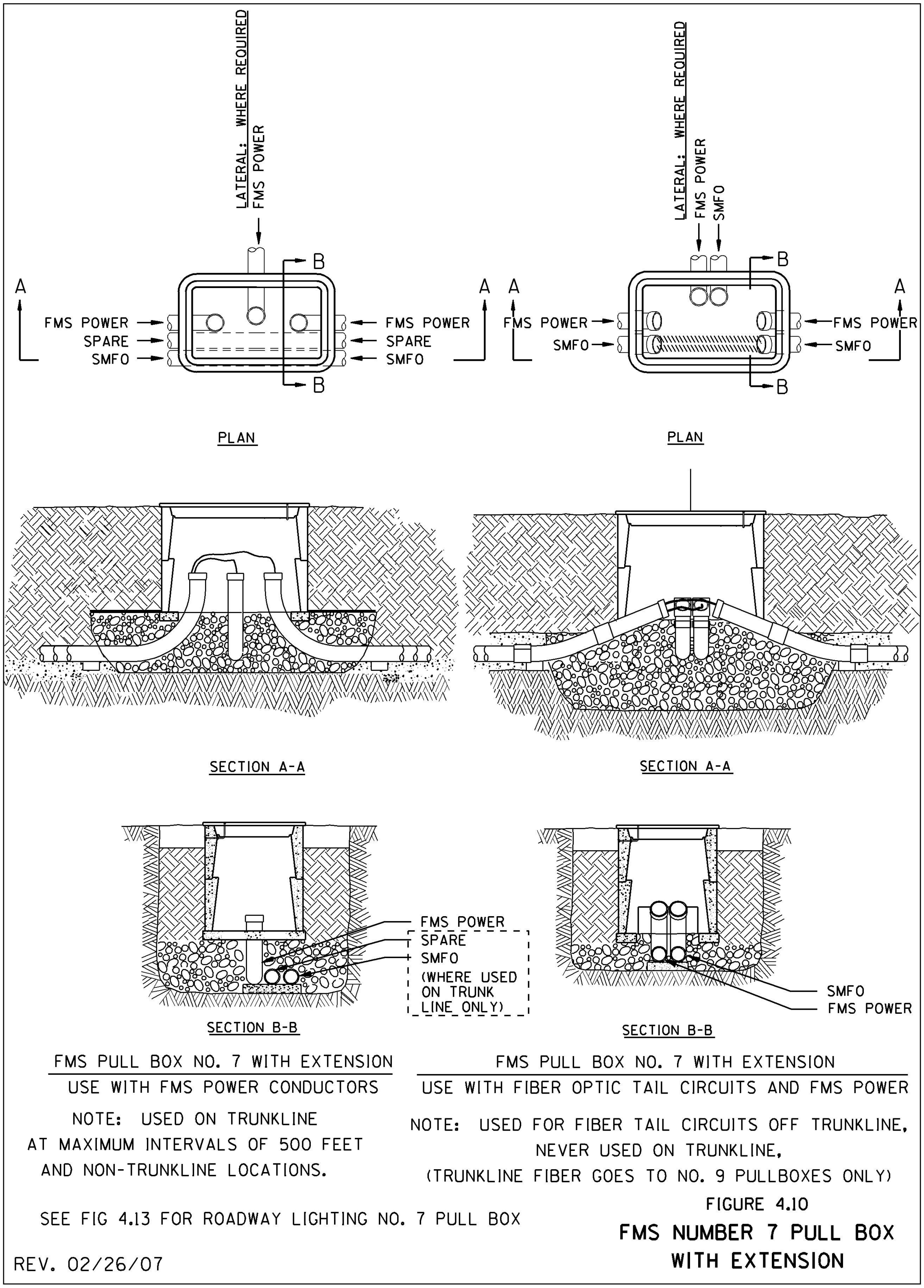

Figure 4.10 FMS Number 7 Pullbox with Extension

4.7.1.3 No. 9 Pullboxes - General

No. 9 pullboxes with *"Term-a-ducts"* (or equivalent) ports for conduit entry are to be installed in the following instances:

- Approximately every 1500 feet along the trunkline to assist installation of fiber cabling within the conduit (In the rare case where there is a continuous mile without interchanges, No. 9 pullboxes may be spaced 1,760 feet (1/3 mile) to conform to the 1 mile spacing of traffic monitoring stations.)
- In the vicinity of each mainline detector station, approximately one- mile spacing
- Each location where fiber-optic cable splicing occurs or may occur.
- Potential splice points for tail circuit cable to Freeway DMS controllers, CCTV cameras, traffic signal controllers or other field devices.

Placement of No. 9 pullboxes should also consider the conduit routing be placed on each terminus of HDD conduits, at each end of structures, at node building sites and at logical regional communication tie points.

See Figures 2.1, 4.1, 4.2, 4.3, 4.6, and 4.9 for placement of field element devices relative to the trunk conduit system.

4.7.1.4 No. 9 Pullboxes – Loading Requirements

FMS No. 9 pull boxes not located in paved or other areas where repeated wheel loads are expected shall be designed, tested, and certified to meet AASHTO *"HS10-44"* and ASTM C 857 *"A-8"* loading requirements, excluding impact factor. This design load would be appropriate for slow moving wheel loads by ADOT maintenance and landscaping vehicles. The AASHTO loading applies regardless of whether the older Load Factor Design (*LFD*) or newer Load and Resistance Factor Design (*LRFD*) methods are used. Note that steel lids for No. 9 pullboxes should be designed to the same design loads required for the remainder of the pullbox (unlike No. 7 with extension pull boxes, where the *allowable stress method* for steel may be used). This standard is easily met since all No. 9 pullboxes require steel lids (see Section 4.7.1.6).

Sample design load calculations, applied to any 8" x 10" area on the pull box lid:

LFD: 8,000 lbs x 1.3 x 1.67 = 17,368 lbs

LRFD: 8,000 lbs x 1.75 x 1.2 = 16,800 lbs

Where No. 9 pullboxes must be located within the traveled way, shoulder, other paved surface, or other location where repeated dynamic loads are likely (such as unpaved areas near ramp gores), a special design of the pullbox lid must be conducted by the designer to accommodate the repetitive vehicular loading. The pullbox lid design must incorporate a locking mechanism that will prevent vibration and vehicle traffic from un-seating the lid. This design should be coordinated with the ADOT TTG project manager.

4.7.1.5 No. 9 Pullbox – Cable Racking

Fiber-optic cable is coiled in No. 9 boxes. The cables are supported on the sides of the pullbox with pre-manufactured vertical cable racks called *cable ladders*. Trunkline conduits typically enter the No. 9 pullbox from opposite corners. See Figure 4.11.

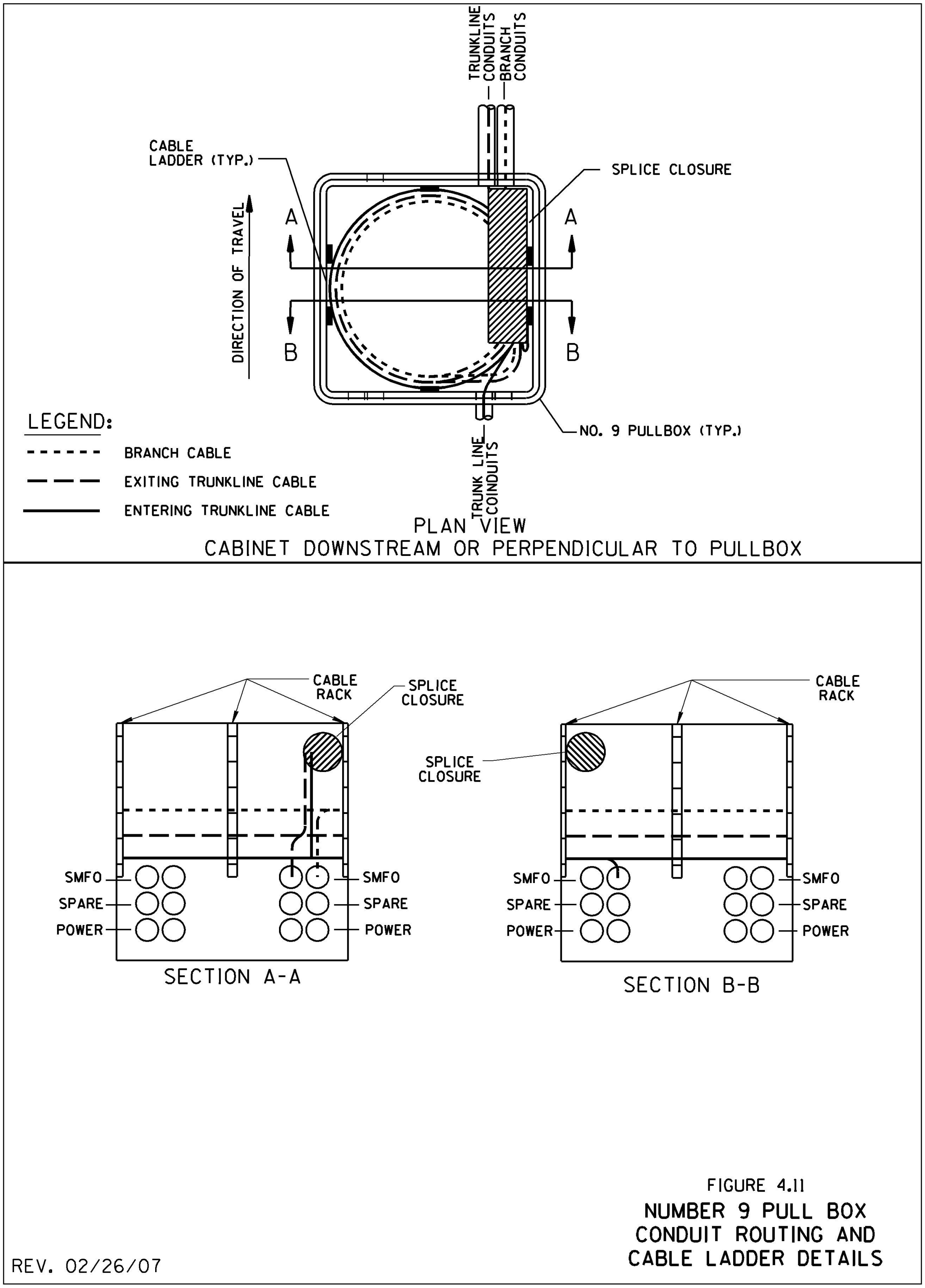

Figure 4.11 Number 9 Pullbox Conduit Routing

4.7.1.6 No. 9 Pullbox – Torsion Assist Lid

The diamond-plate steel lid for No. 9 pullboxes shown on ADOT Standard Drawing TS 1-7 is discontinued for FMS use. No. 9 pullboxes shall incorporate a new lid design with the following requirements (see Figure 4.12):

- Single hinged lid, stainless steel
- Generally open to 180 degrees, (intermediate opening shall not be allowed)
- Failsafe lid lock in open position
- Torsion assist by stainless steel spring mechanism, not hydraulic or fluid system
- Torsion assist in both directions
- Locking hardware, stainless steel

Lift effort opening and closing shall not exceed 30 pounds of force.

4.7.1.7 No. 9 Pullbox – Splice Closures

Stand-alone splice closures for fiber-optic cables include housing, splice trays, fiber-optic splices, and splice protective sleeves. Splice closures should meet Telcordia GR-771-CORE Standards and be compatible with the type of fiber-optic cable used. Splice protective sleeves should be the heat shrink type.

4.7.1.8 No. 9 Pullbox – Numbering and Geo-referencing

No. 9 pullboxes shall be numbered and geo-referenced. No. 9 Pullboxes on each FMS project shall be designated with a unique number that is not duplicated. Re-use of pullbox numbers on each plan sheet shall no longer be an acceptable design format. The pullbox numbering scheme should be similar to the ADOT cabinet numbering scheme, e.g., by route, direction, and post mile to nearest hundredth mile.

Designer's special provisions must include the "as-built documentation" bid item. The Contractor must provide GPS coordinates under the bid item for each new and existing No. 9 pullboxes within the project limits. GPS devices have been secured under previous contracts and will be available for future use. GPS devices should not be a bid item unless otherwise directed by ADOT TTG. The GPS data should be in a machine-readable format, i.e., an ASCII text file. The designer's plans need to provide placeholders for the Contractor to fill in coordinates to record as-built information.

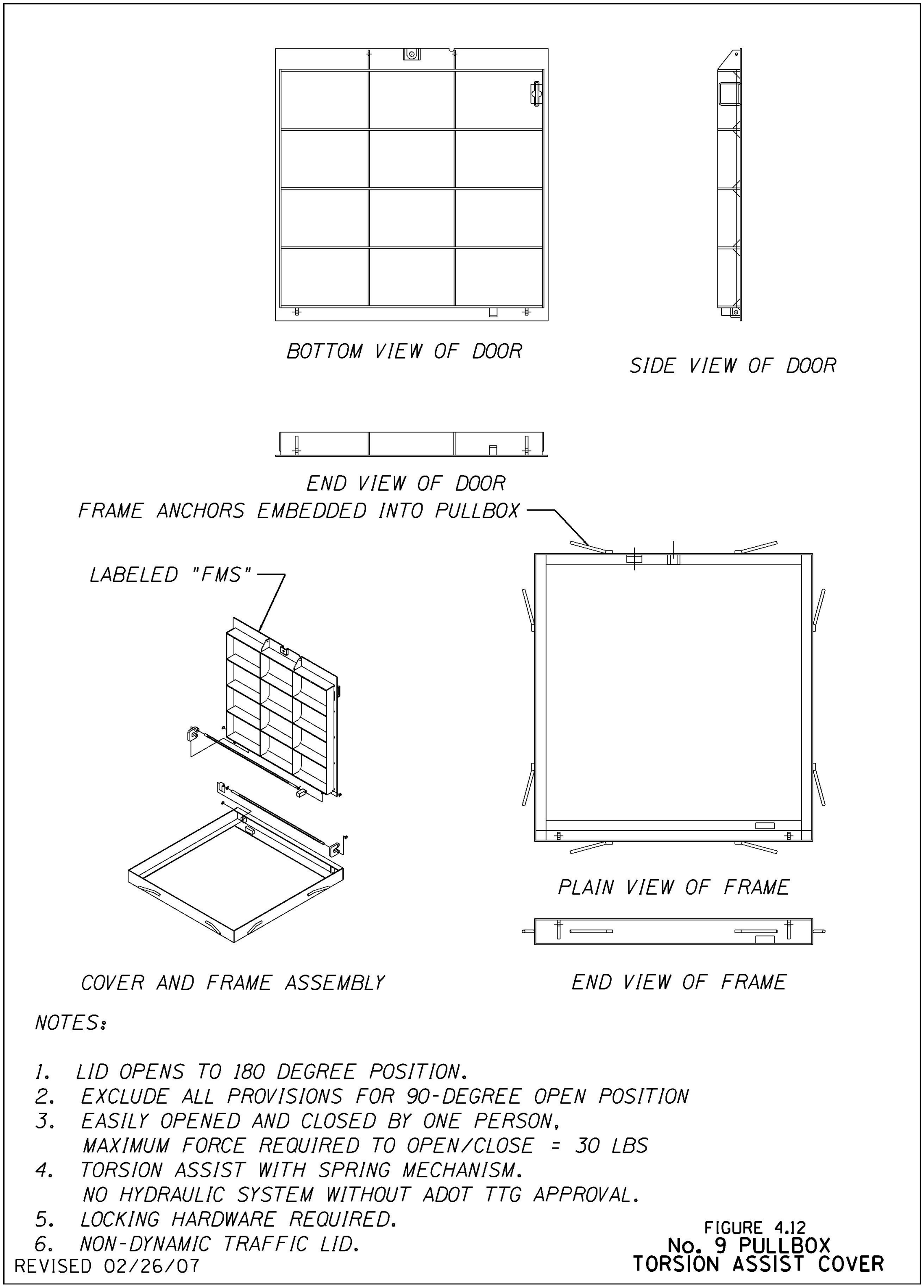

Figure 4.12 Number 9 Pullbox Torsion Assist Cover

4.7.1.9 Pole Mounted Junction Boxes

All poles intended to support non-intrusive vehicle detectors (such as PADs) shall be accompanied with an adjacent pullbox. The pullbox may be placed in the ground (No. 7 with extension) or, in cases of barrier pole mount sites, a special NEMA junction box mounted on the pole near the base of the pole shall be designed. Pullboxes in barriers are not required unless directed by the ADOT TTG PM.

4.7.1.10 Bridge Mounted Junction Boxes

Conduit crossings over canals, roadway undercrossings, railroads, etc that are to be mounted exterior to a bridge facia shall have secure junction box covers added. The junction box covers shall be designed such that special tools are required for the cover plate to be removed to thwart vandalism.

4.7.2 Co-Locating Lighting No. 7 Pullboxes with FMS Trunkline Pullboxes.

As noted in Section 4.4, lighting power conduit may be co-located with the FMS trunkline where it is advantageous though this is not the preference of the lighting maintenance group or ADOT FMS maintenance. No. 7 lighting pullboxes should be co-located with FMS No. 9 and No. 7 (with extension) pullboxes. This assures that the lighting conduit can be accessed without disturbing the trunkline and FMS power cables where they are co-located. See Figure 4.13.

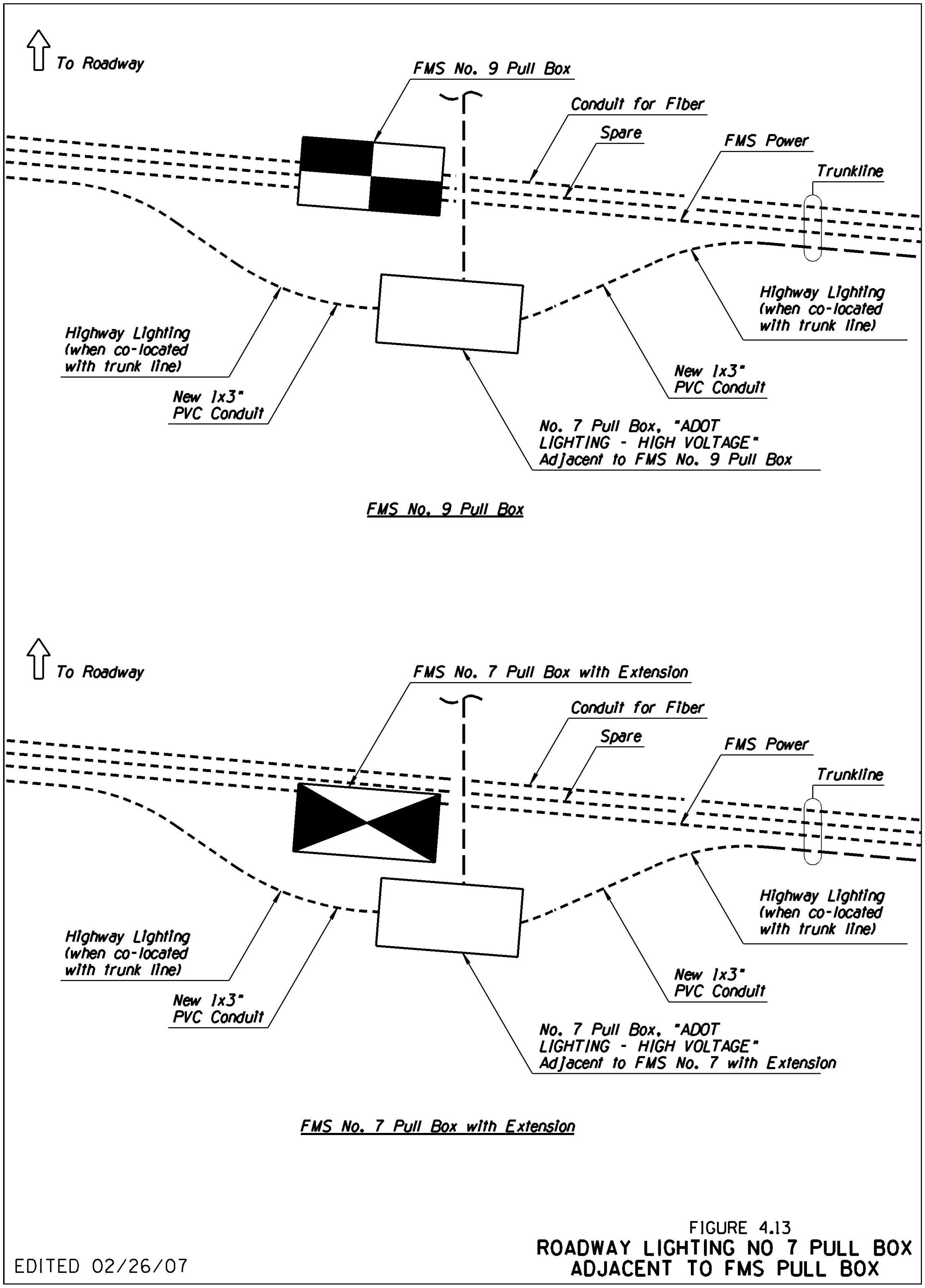

Figure 4.13 Roadway Lighting No. 7 Pullbox

4.7.3 Cable Labeling at Pullboxes

Durable labels approved by the engineer should be installed on each conductor/bundle of conductors and cable near the point where it enters/exits the pullbox. A cable passing through a pullbox, whether spliced or not, will have two labels, one near each exit/entry point within the pullbox. The cable label shall be designed to slide along the cable to facilitate examination.

The two labels for the cable will be similar, but will always differ in the "destination". A typical trunkline No. 9 pullbox with one tail circuit fiber-optic cable would have three labels, two on the trunkline fiber-optic cable (one on each side of the splice closure), and one on the tail circuit cable. All labels should include, where applicable:

- The word "CAUTION"
- Cable type and number of strands/conductors, such as:
- "SMFO96" (single mode fiber-optic, (SMFO 96 strands)
- "AWG6" (American Wire Gauge, No. 6)
- "IMSA 5" (IMSA 19-1 5 conductor cable, IMSA 50-2, etc.)
- "DLC" (Detector Loop Cable)
- Loop Detector Lead-In Cable
- Composite (typically vendor supplied, specific for CCTV, Freeway DMS or non-intrusive detection technology applications)
- Voltage
- "480 Volts"
- "120 Volts"
- (low voltage cables do not need to be labeled for voltage)
- Destination – The following table suggests a destination labeling strategy intended to be consistent, simple to create and simple to use

Table 4.3 Destination Labeling Strategy

CABLE LABELING: DESTINATIONS "TO_________":			
TYPE	**USE**	**DESTINATION**	**EXAMPLES**
Fiber-optic	Trunk	Next: Terminal point for FMS segment Node Building	"TO Val Vista" "TO Node 12" "TO TOC"
Fiber-optic	Tail	Trunkline & side of freeway	"TO EB Trunkline"
		Cabinet Number	"TO CAB 3118253"
Power	Load Center to Cabinet	Load Center Number	"TO LC 3118256"
		Transformer Number	"TO XFRM 3118279"
		Cabinet Number	"TO CAB 3118253"
Loop Lead-In Cables	Detector Loops to Pullbox	Lane Number, "U" – Upstream or "D" – Downstream	"TO 5U" (to lane 5 upstream loop)
Detector Loop Cables	Loop Station to Cabinet	Loop Station: Mainline: Direction of travel Ramp: Start and end ramp direction	"TO EB Loop Station" "To E-N Loop Station"
		Cabinet Number	"TO CAB 3118253"
PAD Cables	PAD No. ___ to Cabinet	PAD	"TO PAD 3118267"
		Cabinet Number	"TO CAB 3118253"

- Cable labels may be bundled around multiple conductors. For example, where power conductors are coming from one load center and going to four cabinets:
  - The conductors coming from the load center entrance to the pullbox may be bundled with a label "TO LOAD CENTER ____"
  - The conductors heading to the four individual cabinets would have one label per cabinet, thus four bundles, each labeled with the appropriate cabinet number "TO CAB _______"

4.7.4 Fiber-optic Cable Installation Sequential Reports

After each cable installation, the Contractor should record the fiber cable foot marking at the entrance and exit point in each No. 9 pullbox for each fiber cable on a Fiber-optic Cable Installation Sequential Report. This report should be submitted to ADOT prior to final acceptance.

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